

# Block III Maser Implementation Program

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*The implementation of the Block III Maser System into the 64-m and 26-m antenna Deep Space Stations has recently been completed. The Block III maser system has improved the reliability and microwave performance over that of the previous Block II maser system.*

*The Block III traveling wave maser amplifier has  $45 \pm 1$  dB gain at a center frequency of 2285 MHz, with an instantaneous 1-dB bandwidth of 30 MHz minimum. The higher gain and lower noise temperature of the Block III maser system have lowered the overall system temperature approximately 10 K.*

## I. Introduction

The implementation of the Block III maser system into the 64-m and 26-m antenna stations of the Deep Space Network (DSN) has recently been completed. Block III maser equipment has also been delivered to the Space-flight Tracking and Data Network (STDN).

The Block I maser system originally installed in the DSN was designed to operate as described in Table 1, DSN mode. The equipment was later changed to the Block II configuration, which allowed remote tuning to either the DSN mode or the Manned Space Flight Network (MSFN) mode as described in Table 1<sup>1</sup>. The Block II maser system included two traveling wave maser amplifiers. Three stations in the DSN were implemented with Block II maser systems to support the Apollo program.

<sup>1</sup>The MSFN is now a part of the STDN.

Following the Block II maser implementation, the development of an improved closed cycle refrigeration (CCR) system and an S-band traveling wave maser amplifier with improved performance characteristics took place at JPL (Refs. 1 and 2). These developments provided the basis for a new maser system design featuring increased refrigeration system reliability and substantially improved microwave performance. This availability of improved performance and the desire to implement all DSN stations with dual maser amplifiers led to the Block III maser implementation program. This report covers the maser amplifier and associated assemblies portion of the implementation program.

## II. Program Description

The objective of the Block III maser implementation program was to produce maser systems which met the performance characteristics listed in Table 1 in a field

operational environment and which provided interchangeability of major subassemblies and components to facilitate field maintenance. The program included the development, design, documentation, fabrication, and testing of 27 Block III maser amplifier assemblies, of which four were delivered to the STDN.

The initial effort in the program was to produce manufacturing documentation, fabrication drawings, and procedures, based on a detailed review of the maser development work previously mentioned (Ref. 2). Additional design work was required to produce an operational Block III maser assembly which would meet the program objectives with repeatability.

The fabrication and testing phases of the program were divided into two parts. Complete subassemblies and piece parts were procured to specified documentation from outside sources where possible. JPL's effort was used for only those areas, such as the following, where special techniques were involved:

- (1) Isolator fabrication and testing.
- (2) Maser slow-wave structure assembly and testing.
- (3) Magnet assembly charging process.
- (4) Maser and refrigerator integration with adjustment and alignment to meet performance characteristics specified.
- (5) Final acceptance testing of the maser assembly in the final package configuration.

### III. Maser Description

The Block III maser assembly is shown in Fig. 1 with the major subassemblies indicated. The majority of the subassemblies are similar in function to those used on the development maser (Ref. 2).

The input signal is coupled to the maser amplifier thru a 30-dB crossguide coupler, end-on waveguide transition and 22-mm coaxial line which extends through the refrigerator to the input of the maser amplifier. Input match tuning is provided at the waveguide transition for interface match adjustments between the maser amplifier, coaxial line and waveguide transition. The coaxial input line extends through the refrigerator and is cooled by a quarter wave thermal short (Ref. 3) to reduce its noise contribution.

The output signal is coupled through the refrigerator with a 22-mm coaxial line, similar to the input line, to a 12.7-GHz reject filter and is then connected to the coupler panel assembly with a semirigid cable. The 12.7-GHz filter provides a minimum of 80 dB rejection over the pump frequency range of 12.66 to 12.72 GHz and has a maximum of 0.2 dB loss at the signal frequency.

The klystron assembly provides approximately 100 mW power in a pump frequency range of 12.66 to 12.72 GHz. A variable attenuator for setting the proper pump saturation level is used. The noise calibration and coupler panel assemblies provide noise injection and the necessary switching for gain calibration of the maser assembly. The magnet assembly is mounted in the lower portion of the frame and provides the maser slow-wave structure with a uniform field strength of approximately 2500 gauss. A field-aiding trim coil, mounted on each pole piece, provides the required field strength adjustment.

Proper ruby *c*-axis alignment with respect to the magnet assembly involved the accumulated tolerances of many interfaces. The interface surfaces between the maser slow-wave structure, refrigerator, frame, and magnet assembly were designed to maintain the magnetic field perpendicular to the *c*-axis of the ruby, in the slow-wave structure, within  $\pm 0.5$  deg. It has been found at S-band frequencies that a *c*-axis misalignment of 1.0 deg to the magnet field causes a gain degradation of 5 dB in the Block III masers.

The maser slow-wave structure containing the ruby bars and isolators is shown in Fig. 2. The ruby bars and ruby isolator mounting strips were procured from Union Carbide with the *c*-axis alignment specified to be accurate within  $\pm 0.25$  deg. The typical ruby bar *c*-axis alignment was accurate within  $\pm 0.1$  deg. The isolators were fabricated at JPL and improvements in the fabricating, sorting, and assembling techniques produced reverse-to-forward loss ratios in excess of 200 to 1. The isolators are capable of  $\pm 2$  deg rotation in the magnet field without detectable performance degradation.

Magnetic field shape adjustment is required to set the gain and bandwidth of the maser to the proper values. Field spreading adjustment to achieve the required bandwidth is accomplished with two coils connected in a figure-eight manner with one aiding and one bucking the main magnetic field. Initial field spreading is achieved with a soft iron shim mounted under the aiding coil. The maser is adjusted for proper gain with a second iron shim which is mounted on the maser cover.

## IV. Maser Performance

The gain vs frequency response of a typical Block III maser assembly is shown in Fig. 3. The gain was adjusted to the specified 45 dB at the peaks, and the bandwidth easily met the required 30 MHz at the 1-dB points. During preshipment acceptance tests, when the response curve was drawn, the magnet current, field spreading current, vapor pressure gauge reading, and klystron frequency were recorded on the graph. By comparing these values with those obtained after installation, the slightest performance variation can be detected. The Block III maser performance at the DSN stations was found to be in close agreement with preshipment test data.

The noise temperature was measured prior to shipment, using an ambient termination and calibrated nitrogen-cooled waveguide termination, at 2270 MHz, 2285 MHz, and 2300 MHz. The noise temperature distribution as a function of frequency and maser assembly quantity is shown in Fig. 4.

Figure 5 is a bar graph which shows the reported system temperatures for both masers (dual installation) at the 26-m antenna Deep Space Stations indicated. The

results indicate an approximate 10 K lower noise temperature than the previous Block I maser systems. Two of the 64-m antenna Deep Space Stations have reported the following system noise temperatures:

Station	43	63
Maser 1	22 K	26 K
Maser 2	26 K	30 K

The DSN stations have reported a typical gain stability of  $\pm 0.02$  dB for durations of 10 s and  $\pm 0.3$  dB for durations of 12 h.

## V. Conclusion

Performance results indicate that the Block III maser assemblies have met the performance requirements with considerable margin. The Block III masers have reduced the overall system equivalent noise temperature by 10 K and provided bandwidths exceeding that required. The previously mentioned objectives of the program have been achieved. Major subassemblies are interchangeable, and additional units can be procured to meet released documentation.

## Acknowledgment

The success of the Block III maser implementation program was due to the combined efforts of many people at the Jet Propulsion Laboratory. Thanks are especially due to the members of the Microwave Electronics Group, R. Clauss, E. Wiebe, R. Quinn, and D. Hofhine, under the direction of Dr. W. Higa.

## References

1. Higa, W. H., and Wiebe, E., "A Simplified Approach to Heat Exchange Construction for Cryogenic Refrigerators," *Cryogenic Technology*, Mar./Apr. 1967.
2. Clauss, R., "Low Noise Receivers: Microwave Maser Development, Second Generation Masers," *The Deep Space Network*, Space Summary 37-47, Vol. II, pp. 71-73, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 30, 1967.
3. Clauss, R., *A Traveling Wave Maser for Deep Space Communication at 2295 and 2388 MHz*, Technical Report 32-1072, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1967.

**Table 1. Maser assembly functional characteristics**

Characteristic	Required performance		
	Block I/II maser		Block III maser
	DSN mode	MSFN mode	
Center frequency, MHz	2295	2280	2285
Minimum bandwidth (1 dB), MHz	10	20	30
Minimum bandwidth (3 dB), MHz	15	24	40
Gain, dB	35 $\pm$ 1	27 $\pm$ 1	45 $\pm$ 1
Gain stability			
Short term	$\pm$ 0.05 dB/10 s	$\pm$ 0.05 dB/10 s	$\pm$ 0.05 dB/10 s
Long term	$\pm$ 0.5 dB/12 h	$\pm$ 0.5 dB/12 h	$\pm$ 0.5 dB/12 h
Maximum voltage standing wave ratio			
Input	1.3	1.3	1.3
Output	1.5	1.5	1.5
Effective input			
Maximum noise temperature, K	12	14	8

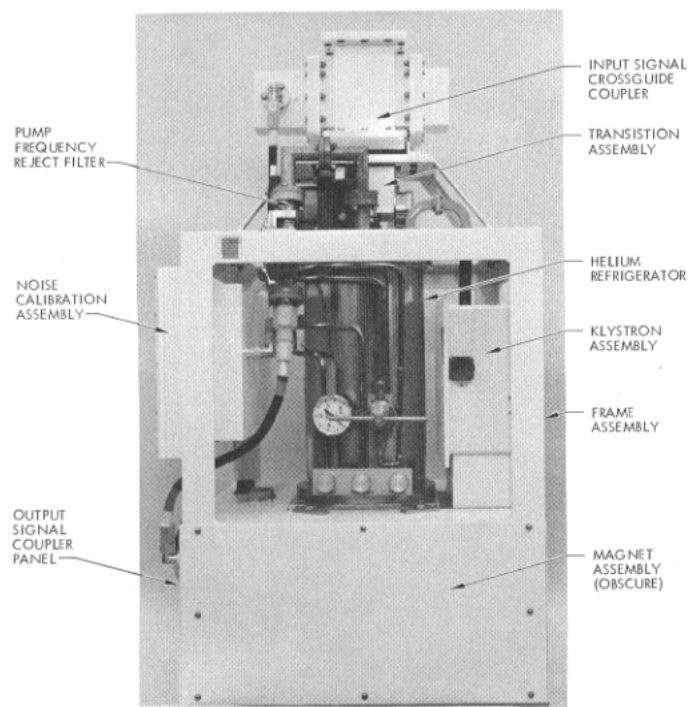


Fig. 1. Block III maser assembly

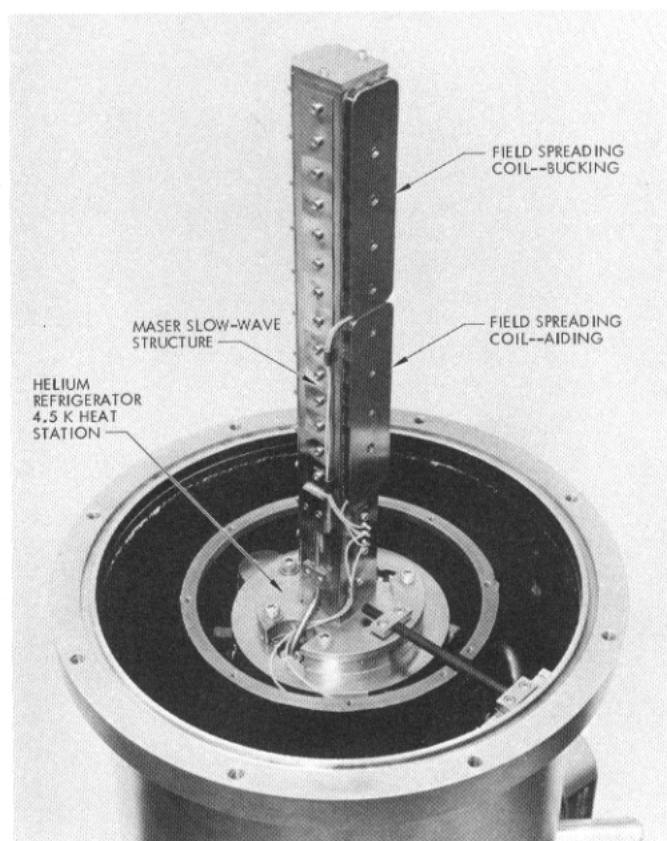


Fig. 2. Maser amplifier mounted on helium refrigerator

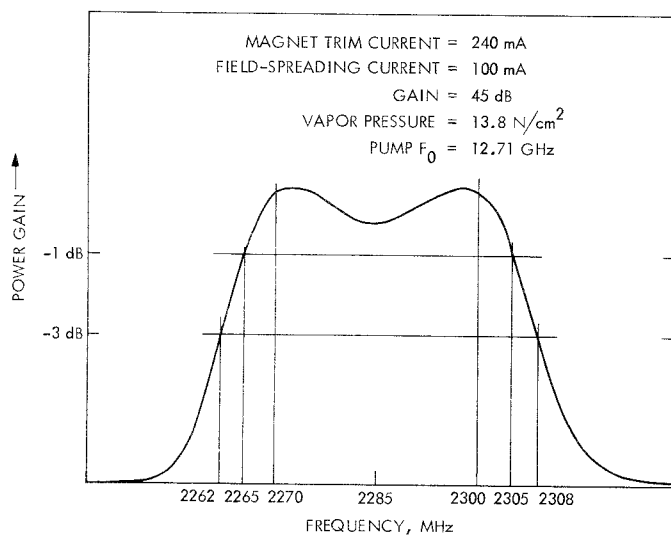


Fig. 3. Block III maser response (TWM Serial No. 018)

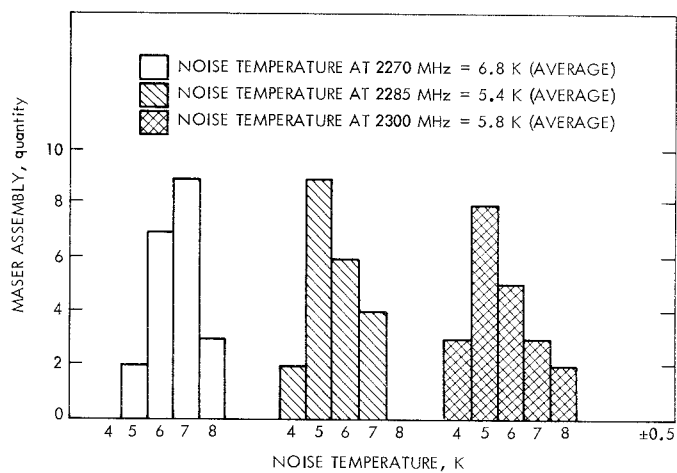


Fig. 4. Noise temperature distribution vs quantity

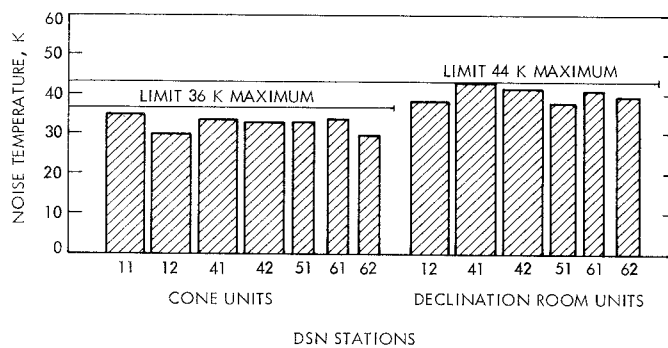


Fig. 5. System equivalent input noise temperatures